

“THE MONOLITH” CONCEPT
AN NEW IDEA FOR FIRE AND FROST PROTECTION
AND NEW LINER
FOR RESTORATION OF EXISTING TUNNELS
BASED ON EXAMPLE OF
THE FESTNINGSTUNNEL IN OSLO

Abstrakt:

This concept to solve the water, frost and fire problems in the existing tunnels basically consists of spraying a 5mm thick waterproofing membrane (TekFlex), a 60mm frost- and fireproofing membrane (Pyrocoat) and a 3mm wear-/ protection membrane (TekFlex) on to the existing concrete liner. The first proposal to use this solution was presented by Jan C. Cappelen by Festningstunnel in Oslo.

TekFlex is based on a mixture of cement and Latex (“flexible” concrete) and Pyrocoat consist of cement, gypsum and vermiculite. They react like other cement based products (when mixed with water) and form a strong physical and chemical bond with each other – a “monolithic” structure.

One can also think of the proposal as a “sandwich”, where each layer is sprayed on to the existing liner after thorough cleaned to ensure maximum bond.

Both TekFlex and Pyrocoat are products, which have over the past 10 years been used on various projects ranging from mining, tunnelling and airports (public infrastructure, red).

TekFlex is used both as a water barrier (takes pressure up to 8 bar) and for rock stabilisation.

Pyrocoat is mainly designed for fire protection, but it also has good insulating properties. In the proposal the Pyrocoat layer is capable of withstanding a 300MW fire over 2 hours, which is more than 15 times the standard requirement. The thickness of the Pyrocoat is depending also from frost isolation requirements.

The calculation of the thickness of the Pyrocoat layer in case of Festningstunnel was based on information submitted by Vegvesenet “that the water freezes first when it reaches the surface of the concrete liner ... and there is no apparent damage to the concrete due to frost”.

This in turn means that the temperature is/ has always been above 0°C at the point of leakage, which is explained by the “heat exchange” from the surrounding rock and ground water.

By using this observation for the theoretical calculation, a 40mm thick Pyrocoat was necessary as an insulation layer.

However, this approach is depending on designer’s requirements and temperature of the rocks. It means that thickness of the Pyrocoat can be varied to meet the insulation requirements.

The Festningstunnel the proposal was a “stand-alone basis”, but it can easily be integrated with other ideas such as pre-cast/ manufactured elements, “false ceilings” etc.

In terms of the visual aspects of the Monolith: TekFlex surface not only protect Pyrocoat again weathering but it is attempted to create a harmonious/ relaxing impression with the use of colours and light.

Festningstunnel – key data

The Festningstunnel was opened to traffic in 1990 and was an important contribution to improve the traffic condition in central Oslo.

The tunnel consists of two tubes, each with a length of 1850m where 330m is a concrete liner in loose ground formation. The balance of 1520m is basically a rock tunnel. Each tube has 3 traffic lanes and on/off ramps. (The traffic density is 85 000 vehicles per day, red).

There are two types of tunnel liners: “watertight” concrete liner and a drained in-situ place concrete safety liner. The concrete has a designed thickness of 350 to 700mm and is unreinforced.

The Problem

The water and frost problems in the Festningstunnel are caused by stresses in the liner due to the relative low temperatures in the winter months. When these exceed the tensile strength, the concrete will crack. As foreseen, initially the cracks have been closed through injection.

However, the movement over a year’s temperature cycle is proven to be too great for the injection materials. In the winter periods the cracks re-open causing new leakage. The same cracks have unsuccessfully been re-injected and/or new cracks have formed nearby.

The problem will most likely be solved, by stabilising the temperature of the concrete liner. This can be done as proposed with a waterproofing membrane and an insulating layer.

Conditions and Limitations

1. The existing concrete liner shall remain in its present form.
By taking into account (in part) the very poor ground conditions, any change could cause stability problems resulting in rock fall or total tunnel collapse.
2. The traffic requirements put limitations on the amount of free space available for new materials and installations. This space is ca 80mm (ref. submitted drawings).
3. The materials proposed for the solution shall be non-flammable. The use of PE foam is not allowed.

The proposed solution shall meet the static and dynamic loads requirements.

The Proposal and its advantages

The proposal was based on a waterproofing membrane and an insulating layer sprayed directly onto the existing concrete liner.

Compared to other “free standing”/ “hang-on” solutions this offered the following advantages:

- Seals all cracks and protect the liner against temperature variations
- Space saving
- Is not affected by air pressure from the traffic
- Solves potential leakage problems at bolt holes
- Easy to repair, no need for specialised equipment nor prefabricated components with long delivery times
- Simple and standard work processes, safe working environment
- Environmentally friendly products

Water protection

To stop water penetrating into the tunnel the concrete surface was to be sealed with a layer of TekFlex.

The membrane was applied by spraying the liquid solution using standard equipment. It is necessary to clean the surface prior to spraying using a water blasting technique. The TekFlex mixture sticks well to the concrete surface and forms a waterproof membrane.

In a hardened state the TekFlex will withstand water pressure in excess of 8bar.

TekFlex is also flexible in is capable of absorbing movements in the concrete without cracking (temperature related: 70% elasticity at 8°C). TekFlex is water and cement based product, and is therefore not harmful to the environment.

Thickness of membrane: 5mm. At low temperatures the elasticity of TekFlex is considerably reduced. At temperatures below -15°C the TekFlex will attain similar properties to that of concrete. As is the case for the concrete liner it is also necessary to apply insulation to this layer of TekFlex (to maintain some flexibility).

Frost insulation

For frost insulation and fire protection Pyrocoat 800 is used, which basically consists of vermiculite, cement and gypsum.

As for TekFlex, Pyrocoat 800 is applied with standard spraying equipment. The Pyrocoat 800 sticks well and is sprayed directly on to the TekFlex layer.

Fire insulation

Pyrocoat offer very efficient fire protection. In the proposal a Pyrocoat layer of 40mm will withstand a fire of 300MW over 2 hours, which is 15 times better than the prescribed requirements.

Surface Layer

A new membrane of TekFlex is sprayed on top of the frost protective layer. This will protect the Pyrocoat from water and traffic pollutants and it will give the tunnel a light and pleasant surface which is easy to clean.

At very low temperatures the TekFlex becomes brittle and in order to control any potential cracking it is proposed to add Polypropylene fibres to the mixture. If necessary, additional joints can be cut (f.ex.10mm deep in a 3m grid).

Top membrane thickness: 3mm

Safety against explosion

The “sandwich” solution will be an integrated part of the existing structure without any hollow sections or weak points. In case of an explosion, the actual mass and physical properties will help to minimise any damage.

Repair & Maintenance

The outer TekFlex membrane helps to improve the visual impression and act as a wearing surface for cleaning and minor damages. It is easy to “refresh” by applying a new layer, which can be sprayed, painted or rolled on.

Should part of the “sandwich” be damaged it can easily be repaired by one person (similar to that of normal plaster).

Small amounts of accelerators can be mixed with both the TekFlex and the Pyrocoat to optimise the setting time.

Specific areas of the “sandwich” can be removed if required by using a hydraulic spade.

Construction Process

The work can be carried out using 3 teams (one TekFlex and two Pyrocoat teams) each with 4 men. In addition support staff is required, giving a total workforce of ca 20.

Each team is provided with a materials trailer/containers, compressor, generator, amenities, lighting, screens, pumps, cables, hoses etc. incl. a mobile road surface protection cover.

All the equipment is mobile, easy and quick to assemble and disassemble to maximise productivity.

A site is established within 5 min drive from the tunnel entrance for storage of materials and equipment, mixing facilities, spare parts etc.

It is estimated that the total construction time will be ca 130 days or 19 weeks. In order to save time other work in the tunnel such as new technical installations can be carried out parallel to the spraying activities.

Traffic Safety

At present the traveller in the Festningstunnel would find the traffic hectic, causing confusion and stress with high traffic density, on/off ramps, “endless” curves etc.

The lighting is in places blinding and the driver has to be very concentrated, take quick decisions with poor forward view.

In the proposal focus is set on creating a more relaxing driving environment by using better and more colours in the lighting and other surface texture. Monolith coating offers many possible solutions due to saved space and surface of TekFlex.

Of the many possible combinations, the following is favoured:

Continues overhead lighting; one for each lane

Coloured (blue/green) light 45° upward at and 200m before all on/off ramps

Texturing of the surface in some places is foreseen.

Conclusion

There is proposed solution for restoration of an existing tunnel which may be applied in many cases.

The problem of fire protection, temperature stability of construction (Especially in old monolithic tunnels), cracks and water dripping is well known in old tunnels.

The major limitation like space availability, cost and time stay the same. Minova hopes to offer a solution that is worth to consider in practical application.